CROWD-BASED ILLUMINANCE MAPS:
COMPARING DAYLIGHT PERCEPTION IN VIRTUAL REALITY TO EMPIRICAL METRICS

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BIM | VR | User-Oriented Design | AI
Cyber Society | AR | Urban Regeneration
Game Design | Crowd Simulation | Real-time Rendering
Computational Design | Community-based Design
How can daylight performance metrics be more user-oriented?
Introduction

Daylighting Impact on Buildings’ Occupants

- **90%**
  - Time spent indoors

- **16%**
  - Variation of annual learning progress

- **15%**
  - More creative

- **44%**
  - State daylight as 1st need in workplace

- **Up to 40%**
  - Gain in productivity

- **46 mins**
  - More sleep per night

References:
1. (Sustania, 2012)
2. (Barrett, 2015)
3. (Global Human Spaces Report, 2015)
4. (Boubekri, 2014)
The dilemma of Daylight Quantitative Metrics

- Physically accurate.
- Essential for design stage.
- Don’t reflect occupant behavior.
- “Generic” user models.

LEED certified buildings don’t always perform better than their traditional counterparts, and sometimes they perform even worse.

(Newsham et al., 2012)

Illuminance
Luminance
Useful Daylight Illuminance
Daylight Autonomy
Annual Sunlight Exposure

Visual comfort
Productivity
Perception
Behaviors
Occupational rates
Perceptual qualities of daylighting

Assessing daylight based on human perception is as important as quantitative measurements.

(Paredes, 2016)

Immersive Virtual Environments (IVEs) are adequate to investigate human perception of daylighting.

(Chamilothori, 2018)

Immersive: full visual field, sensation of presence.
Virtual: mobile, flexible, safe, economic
Environment: realistic, scale-free, customizable
Limitations on current studies

**Lack of Richness**
- simple, small scale spaces.
- focus on office spaces only.

**Lack of Locomotion**
- one standing point.
- Lack of interaction (customization)

**Lack of Interactivity**
- Questionnaires dependent.
- No integrated challenges/tasks.
How to improve outputs of daylight perception in IVEs against quantitative metrics?

- Photorealistic
- Explorable
- Large-Scale
- Customizable
- Gamified

Crowd-Based Illuminance Maps
Experiment case study

Kimbell Art Museum, Fortworth TX

- By Louis Kahn.
- Unorthodox daylighting qualities.

(kimbellart.org, 2019)
Experiment case study

CPU Rendering

Real life

Real-time Raytracing

(kimbellart.org, 2019)
Experiment workflow

Users are introduced to the experiment room.

A brief introduction about the experiment.

User is asked to wear the headset.

A sample VR scene.

Main VR space (Kimbell Museum).

User is asked to explore different areas of the VR space.

User can switch on or off spotlights.

Change daytime between morning (9AM) and afternoon (6PM).

User is asked to explore different areas of the VR space.

Snapshot the scenes they perceive daylighting differently.

Rank each snapshotted scene as (very dark, dark, bright, very bright).
Experiment workflow
Generating crowd-illuminance maps

Users snapshots

Crowd camera map
Generating crowd-illuminance maps

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Comparing perception maps to quantitative simulations

Crowd based illuminance

Illuminance map (VELUX Daylight Visualizer)

Surround Based Metric?

Ambient environment

Luminous flux on surface
Comparing perception maps to quantitative simulations

Image-based luminosity mean values (9 AM)
Comparing perception maps to quantitative simulations

Correlation between user perception and mean luminosity for a given spot at 9AM

User perception (1=Very Dark, 2=Dark, 3=Bright, 4=Very Bright) vs. mean luminosity values
Comparing perception maps to quantitative simulations

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Future research challenges

Why **mixed perception** happen?

Overcoming VR **limitations**?

Consistency with further daylight metrics?

A **unified metric** that considers both subjective and quantitative qualities of daylighting
THANK YOU

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